Fabrication Of Functional Probes For Nearfield Optic Microscopy

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gases and their partial pressures were maintained at 6.4×10^{-7}, 6.5×10^{-8} and $3.3–4.9 \times 10^{-4}$ atm, respectively. InGaAs emission layers were introduced into the middle of a GaAs micropillar, as emitting layers with wavelength of ~1.0 μm. The operating pressure and the substrate temperature during epitaxy were maintained at 38 Torr and at 750°C, respectively.

The hexagonal micropillars had smooth sidewalls consisting of (110) facets and were perpendicular to the substrate, as shown in Fig. 2. The average hexagonal radius and height of micropillars in Fig. 2 were 101 nm and 1.59 μm, respectively, and thus they have a high aspect ratio of >10.

Side-detected PL measurements were made to study the radiation from the emission layers in the direction perpendicular to the micropillars which had passed through the 2D PBG crystal. The PL spectra were measured in both of *H*- and *E*-polarizations.

In crystals of the form of triangularly arranged hexagonal micropillars, the PBGs are not uniformly in any direction but appears only in certain directions or wavelengths. In Fig. 3, the measured PL spectra are shown in both polarizations in Γ-*J* and Γ-*X* directions in the first Brillouin zone. We found that the measured spectra were discontinuous and that the wavelengths of discontinuous points in the spectra were almost matched with those of the calculated PBG edges, such as 0.88 μm in *E*-polarized spectra in Γ-*J* direction and 0.91 μm in *H*-polarized spectra in Γ-*X* direction. It is obvious that the presence of the PBG in the fabricated crystals resulted in the discontinuity of spectra.

In conclusion, semiconductor 2D PBG crystals have been fabricated by selective MOVPE on (111)B GaAs and their optical characteristics have been demonstrated in both polarizations by side-detected PL for the first time. It has been shown that this selective epitaxy technique is suitable for the fabrication of micropillars. Following this fabrication and observation, we are fabricating a 2D PBG crystal cavity, i.e., a PBG crystal having phase shifts in it.

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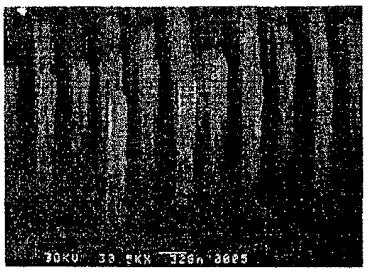
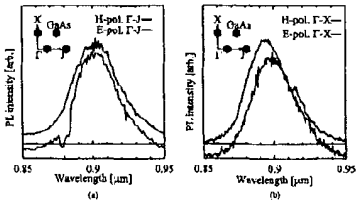


ThK2 Fig. 2. SEM image of hexagonal micropillars arranged in triangle lattice.



ThK2 Fig. 3. PL spectra detected in the direction perpendicular to the micropillars and calculated results of phonic bandgap against the normalized hexagonal size. The spectra were observed in both polarizations separately. The hexagonal size of the measured crystal was ~0.23. (a) Radiation observed in the Γ-*J* direction and (b) in the Γ-*X* direction.

ThK3 **1145**

Fabrication of functional probes for near-field optical microscopy

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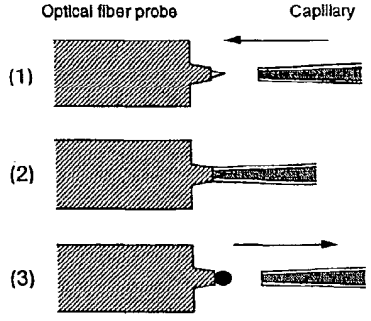
Functional probes for near-field optical microscopy (NOM) are a key device for improving NOM in performance and applying NOM to chemistry and biology. Much effort has been made to fabricate the functional probes, but advances in the fabrication is not enough to make a great impact on NOM.[1]

We present a novel method to fabricate the functional probes by means of a capillary under a system of a conventional optical microscope and micro-manipulator. Functional materials are selectively fixed on the apex of optical fiber probes with a size of about a micron. Figure 1 shows a schematic of the fixation procedure. The capillary is used as a small beaker. The optical fiber probe is prepared with the SRC method.[2] The capillaries are prepared by pulling glass tubes with a puller for micro-electrodes.



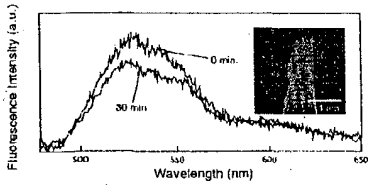
ThK3 Fig. 1. Schematic of fixation procedure under a system of a optical microscope and micro-manipulators.

The functional materials are dissolved in solvents and made low in viscosity to fill the top of capillaries. The capillary method[3] is applicable in fixing many kinds of functional materials.

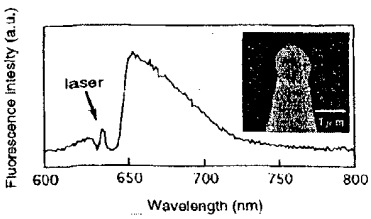
In the SEM image of Fig. 2, poly(vinyl chloride) (PVC) film including fluorescein is fixed on the apex of the probe and gives a function of chemical sensor to the probe. The PVC film[4] is an attractive organic membrane which enables us to produce ion-selective membrane based on ion-exchange mechanism by dissolving ionophores with fluorescent indicators. The sensor size is from submicron to micron, depending on the fixation condition, especially depth of dipping the probe, diameter of the capillary and viscosity of the PVC film. The viscosity is adjusted with a solvent of Terahydrofuran (THF). In Fig. 2, typical fluorescence spectrum is shown when illuminating the probe with 488 nm of Ar-ion laser coupled to the fiber at a power of 0.2 mW. 70% of photobleaching is observed within 30 minutes.

In the SEM image of Fig. 3, polydiacetylene (PDA) 3ECMU is fixed on the apex of the probe. PDA is an organic polymer with large third-order nonlinear susceptibilities resulting from one-dimensional π-conjugated electrons. In near-field regions, optical processes of nonlinearity such as four-wave mixing and phase conjugation are not yet clear.[5] The nonlinear probes are direct tools to investigate nonlinearity in the near-field regions. In Fig. 3, fluorescence spectrum is shown when the probe is resonantly excited by 632.8 nm of He-Ne laser coupled to the fiber at a power of 2 mW. The probe with PDA is also used as light-emitting probes.

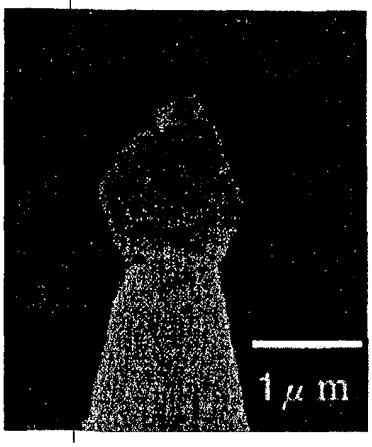
Figure 4 shows the probe with GaAs powder which is fixed on the glass surface of the optical fiber because of adsorption. Ethanol is used as solvent for GaAs powder which is prepared by crushing GaAs wafer in a mortar for about an hour. The apex of the probe is



ThK3 Fig. 2. The SEM image and fluorescence spectrum of the probe with PVC film containing fluorescein.



ThK3 Fig. 3. The SEM image and fluorescence spectrum of the probe with PDA 3ECMU.



ThK3 Fig. 4. The SEM image of the probe with GaAs powder.

attached to accumulated GaAs powder at the top of the capillary because of ethanol evaporation. The probe with GaAs suggests that it is possible to fix powder on the apex of the optical fiber probes without adhesive agents.

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ThK4 **1200**

Fabrication of polymer microlens arrays by means of a UV-curing technique

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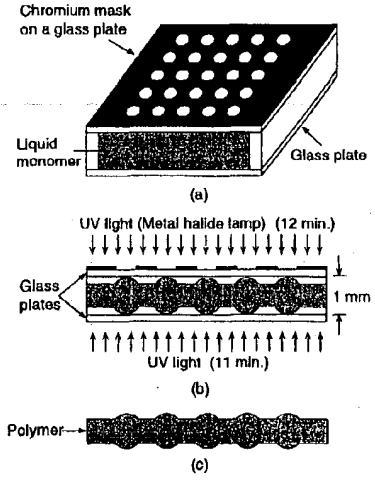
Polymer materials are suitable for optical elements because they are light, inexpensive, highly shock-resistant, and easy to process. Several methods have already been reported for making polymer micro-optics elements, among them are injection moulding, hot pressing,[1] excimer laser irradiation with styrene diffusion,[2] and use of the photothermal effect by infrared radiation.[3] In this paper we propose a new fabrication method for microlens arrays and phase gratings, which use the contracting effect of photopolymers occurring when they are exposed to ultraviolet (UV) light for curing.

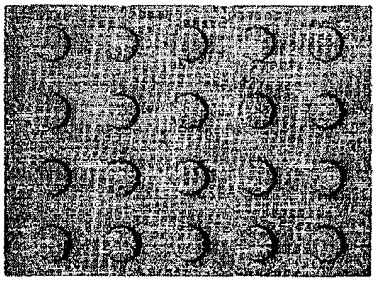
UV-cured polymer is used mainly for the fabrication system of three-dimensional prototypes. One of the problems encountered in this system is that the polymer contracts in the process of UV curing, which leads to the size error in the resultant product. We exploit this property to produce protrusion or corrugation on a polymer substrate.

The fabrication process for a lenslet array is schematically illustrated in Fig. 1. First, UV-curable liquid monomer (TEMA) is poured into a glass cell with internal dimensions of 75 × 75 × 1 mm [Fig. 1(a)]. A chromium mask with periodically arranged circular apertures on quartz is placed on top of the cell. Next, the liquid monomer is irradiated from above for one minute by a metal halide lamp that has the radiation spectrum ranging from 200 to 400 nm [Fig. 1(b)]. The UV light induces photo-polymerization, and the medium begins to contract as it changes from the liquid phase to the solid one. Owing to this contracting effect, a force is produced which make the monomers in the shadow domains of the medium move into the irradiated domains to join the polymerization, forming protrusions on both surfaces of the polymer at the positions corresponding to the circular apertures. Then the irradiation from both the top side and the bottom side for 11 minutes follows to harden the whole medium. After annealing for 1 hour at 120°C, we finally obtain a microlens array plate [Fig. 1(c)].

Figure 2 shows an example of a microlens array fabricated by the UV-curing method. The diameter of each lenslet and the separation of the lenses are 1 mm. The shape of the surface was measured by a profilometer, and it was found that



ThK4 Fig. 1. Schematic diagram of the process for making microlens arrays.



ThK4 Fig. 2. Picture of a microlens array produced by the UV-curing method.

the height of the microlenses was about 8 μm, each of which had a bell shape with the top half of it being in a spherical shape. The profile of the lens depends on the position and the pattern of the metal mask. The optimum conditions for producing high quality microlenses is discussed, together with the results for an optical characterization of the microlens arrays produced under various conditions.

*Tsukuba Research Center, Mitsubishi Chemical Co., Inashiki-gun, Ibaraki 300-03, JAPAN

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ThK5 **1215**

Fabrication of Yb^{3+} doped multi-layer cladding fiber using flash condensation method in MCVD process

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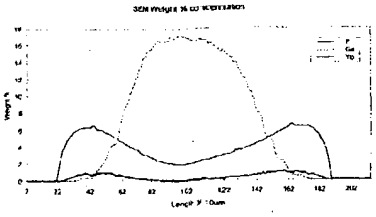
The use of ytterbium in optical communications technology is becoming widespread, because ytterbium exhibits resonant nonlinearities at 1310 nm and 1545 nm (approximately around the standard optical communication minimum loss windows) without introducing any absorption at these wavelengths. Such nonlinearities are potentially useful in switching and altering the signal transmission characteristics depending on the intensities of the pump and input power. To achieve this with low input power, the fiber needs to be doped heavily to induce high nonlinearity.

There are many ways to dope optical fibers with different rare-earth materials. These include Volatile Halide Method, Aerosol Doping, Outside Vapour Deposition, Vapour Axial Deposition, Sol-gel Process, and Solution Doping using MCVD. The common limitation of these methods is the amount of the possible dopants being implanted in the preform. To overcome such limitations, the used method for fabrication of heavily-doped ytterbium optical fibers was Flash-Condensation in MCVD process. This process relies on rapid heating and reaction of acid trapped in a silica frit. The advantage of this method over the above mentioned methods are: (1) uniform incor-



ThK5 Fig. 1. A typical concentration profile of the manufactured multi-cladding fiber.

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